ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: ITRF, plate tectonic and climate change: what insights from geodesy station horizontal motions?

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Host lab/ Team: **IPGP- Team Geodesy – UMR7154**

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Doctoral contract with or without teaching assignment

Presentation of the subject: (Maximum 2 pages)

The IPGP-IGN Geodesy team has been responsible for the realization, maintenance, and improvement of the International Terrestrial Reference Frame (ITRF) for over 30 years, a necessary reference frame for defining precise positions on Earth and in orbit, in particular with space geodesy methods. With each realization of the reference frame, we develop a plate tectonic model based on velocities from the reference frame stations. The latest solution of the reference frame, called ITRF2020, and its plate tectonic model were published in 2023 [Altamimi et al., 2023a, 2023b]. Since the horizontal movement of space geodesy stations is dominated by the movement of tectonic plates, being able to correct the observations with such a model is essential for any user interested in temporal variations in station positions with centimeter to millimeter precision. This is particularly necessary for the construction of the so-called "regional" frames, such as the European ETRS89 frame, which are co-moving with their tectonic plate. This is also necessary for studying the non-linear horizontal movements of stations induced by viscoelastic deformations of the solid Earth in response to current and past climatic loading, in particular from glacial and hydrological loads.

The ITRF plate tectonic model is classically constructed from the horizontal velocities of stations in so-called "stable" zones, i.e. far from the plate boundaries where the crust is deforming, far from the deformation zones due to post-glacial rebound (in response to the last deglaciation), and far from the deformation zones due to water and ice loadings induced by climate changes. However, relatively recent results question the relevance of the definition of these "stable" zones. Indeed, it appears that horizontal ground deformations induced by past or current glacial loads can extend laterally over distances very far from the source of the deformations. For these reasons, it has been clear for several years that plate tectonic models from the ITRF, like all other classical models of geodetic origin, are very likely to be affected by errors, particularly in North America and Europe. To overcome this problem, it would be necessary to correct geodesy observations using a realistic and accurate postglacial rebound model. Unfortunately, modelling postglacial rebound is a complex problem that suffers from the few constraints we have on the internal rheological parameters of the Earth.

The candidate for this PhD subject will be integrated into the IPGP Geodesy team. His task will be to study and interpret the horizontal movements of space geodesy stations resulting from, among other things, ITRF2020 at different scales of time and space. The first step will be to focus on the linear component of the station movement. This will consist of building a global plate tectonic model consistent with observations and modelling of post-glacial rebound. Drawing on our ITRF expertise and the Earth deformation modelling tools that we have developed, the student will imagine and develop an inverse problem that aims to explain the horizontal velocities of ITRF stations by jointly estimating the poles of rotation of tectonic plates and the movements induced by post-glacial rebound, while considering the internal rheology of the Earth. In a second step, or in parallel, he may focus on the non-linear component of the horizontal movements of the stations. These observations of non-linear horizontal movements are under-exploited for the study of geophysical and climatic processes, partly because they must first be corrected for plate tectonics, and also because they are small in comparison with vertical movements and more difficult to interpret. In particular, they are very sensitive to viscosity in the most superficial layers of the Earth, zones with poorly known rheology. These difficulties can also be advantages. In addition to providing rheological information on the upper parts of the Earth, these movements are more sensitive to the viscous component of viscoelastic deformations. Studying them could allow us to better discern the deformations due to current and past deglaciations in glaciated areas, by combining them with conventional data (vertical movements and spatial gravimetry) which are generally more sensitive to the elastic component. This would allow us to better determine, thanks to space geodesy data, the extent of current ice melting.

References :

Altamimi, Z., Rebischung, P., Collilieux, X., Métivier, L., & Chanard, K. (2023). ITRF2020: an augmented reference frame refining the modeling of nonlinear station motions. Journal of Geodesy, 97(5), 47.

Altamimi, Z., Métivier, L., Rebischung, P., Collilieux, X., Chanard, K., & Barnéoud, J. (2023). ITRF2020 plate motion model. Geophysical Research Letters, 50(24), e2023GL106373.